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Genetic Analysis of Body Conformation and Feed Efficiency Characteristics in a Selected Line of Rhode Island Red Chicken

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ABSTRACT

This investigation aimed to evaluate genetics of body conformation and feed efficiency characteristics in a selected line of Rhode Island Red chicken taking 100 numbers of single hatched out pedigreed chicks at Central Avian Research Institute (India). Data was analyzed by least squares analysis of variance. Least squares means of body weight, shank length, keel length, breast angle, body Weight Gain (WG), Feed Consumption (FC) and Feed Conversion Ratio (FCR) were estimated at various weeks of age. Sires of the chicks significantly ($p<0.05$) influenced the estimates of all the traits throughout the ages with a few exceptions. Chicks' sex also affected ($p<0.05$) the estimates of all the traits excepting 4th week body conformation traits, FC at 6th week onwards and 6th week FCR only. Male birds demonstrated better estimates than females throughout the ages. The FC and 16th week FCR also varied ($p<0.05$) among different feeding groups. All the traits excluding FC were heritable at variable magnitude. The estimates of genetic and phenotypic correlations coefficients were positive in trends with high magnitude among the intra-week body conformation traits and least to high magnitude among various feed efficiency traits. Only WG and FCR were invariably negatively correlated with a range of low to high genetic correlation coefficients. These research-outcomes may serve as base information to the breeders and academicians.

Key words: Body conformation, feed efficiency, genetic and phenotypic correlations, heritability, RIR chicken

INTRODUCTION

Since the inception of Central Avian Research Institute, Izatnagar in 1979, this institute has been rearing exotic Rhode Island Red (RIR) chicken and segregated as RIR selected and control pure lines. The selected line performs better with early sexual maturity, heavy egg size and high egg production even more than its control line and white strain (Das *et al*., 2014a). The chicken lines fit well to the rural backyard system and the farmers are accepting because of high profitability. Consumers prefer a plump-breasted bird because of a preference for white meat. Processors also believe that a plump-breasted bird yields a greater percentage of breast meat than do birds with a less plump breast. The desires of the consumer and processor are reflected back to the breeder, with the avowed intervention of increasing breast-plumpness (Das *et al.,* 2014b). The layer stock is generally selected for high egg production, heavier egg, earlier sexual maturity, higher viability, strong eggshell and optimum body size. Most of these traits are related to the feed efficiency along with its genetic background and improvement in these traits would also be expected to improve feed efficiency (Niranjan and Kataria, 2008). The knowledge of basic genetic parameters like heritability and correlation is of paramount importance to formulate effective breeding plans for improving these economic traits through selection and breeding (Paleja *et al.,* 2008). Hence, this investigation aimed to evaluate genetics of body conformation and feed efficiency characteristics in RIR selected line chicken.

MATERIALS AND METHODS

Experimental birds and procedures: Single hatched out pedigreed 100 chicks of RIR selected line maintained at this Institute were investigated. The chicks were wing banded, dubbed and vaccinated with F strain at the hatchery and subjected to standard battery brooding shelves and litter brooding. Standard floor space and brooding temperature were provided. After attaining the four weeks of age at the battery brooder, the chicks were shifted in to new brooder house for 16 weeks of age. The female birds were then shifted in to cages for laying. Fresh water and feed were provided *at libitum* twice daily with all possible measures adopted to reduce wastage of feed. The birds were fed on the institute-formulated chick mash with 20.65% CP, 2694.64 kcal kg^{-1} ME, calcium-1.02%, available phosphorous-0.45%, lysine-1.05% and methionine-0.41% for 0-8 weeks of age and grower mash with 16.78% CP, 2536.00 kcal kg^{-1} ME, 1.15% Ca, 0.40% P, 0.76% Lys and 0.37% Met for 9-20 weeks. The birds were vaccinated following standard vaccination schedule being followed at this institute (Das *et al*., 2014a, b).

Feeding trials: The feeding trials (*ad lib.*) were conducted from day-1 to 16th week of age crucially maintaining four subgroups under two feeding groups. The birds were provided with weighed quantity of standard ration. The feed residue was weighed after each recording period, followed by notice of any mortality on specific date, if any, the dead bird's (s') wing band number (s) and weight were date-wise recorded and the amount of feed consumed by individual birds per day was calculated.

Traits investigated

Body conformation traits: Chick weight, body weight, shank length, keel length and breast angle at 4th, 6th, 8th, 12th and 16th weeks of age were measured using digital weigh balance for body weights, vernier calipers for shank and keel lengths and goniometer for breast angle-measurement.

Feed consumption efficiency traits: Feed consumption efficiency was expressed as feed consumed (g), body weight gain (g) and feed conversion ratio (feed consumed/weight gain) in different periods of ages.

Statistical analysis: Data was analyzed by least squares analysis of variance (Harvey, 1990) incorporating sire as random effect, sex and or feeding groups as fixed effects in the linear model:

$$Y_{ijk} = \mu+S_i+W_j+H_k+e_{ijkl}$$

where, Y_{ijkl}: value of a trait measured on lth individual belonging to ith sire, jth sex and kth feeding group, μ: overall mean, S_i: random effect of ith sire, W_j: fixed effect of jth sex, H_k: fixed effect of kth feeding group and e_{ijkl}: random error associated with mean zero and variance σ^2. Genetic and phenotypic parameters were estimated using paternal half-sib correlation method (Becker, 1975).

RESULTS AND DISCUSSION

Body conformation traits: Least squares means of Chick Weight (CW), Body Weight (BW), Shank Length (SL), Keel Length (KL) and Breast Angle (BA) at 4th, 6th, 8th, 12th and 16th weeks of age are presented in Table 1. The present chick weight was comparable to the earlier reports in RIR chicks (Das *et al*., 2014a, b; Asharf *et al.,* 2003). The present other estimates were better than the available reports for RIR-white strain chicken (Das *et al.,* 2014b). The present chicken line demonstrated better estimates of body weights at various weeks of age than the available reports for its control and white strains, but lower than the reports for its crosses with males of coloured synthetic broiler male line (CARI-Debendra cross) and white Leghorn IWH line (CARI-Sonali cross) (Das *et al*., 2014b). The present body weights were also better than its crosses with indigenous chickens as evident when compared to the earlier available reports for Fayoumi male × RIR female cross and its reciprocal (El-Magharby *et al*., 1975), RIR × indigenous lines Bare-neck/Betwil/Large Beladi crosses (Mohammed *et al*., 2005). All the body conformation traits at 6th week onwards demonstrated significant higher estimates for males than females (Table 1) in accordance to the earlier report (Das *et al*., 2014b; El-Safty, 2012). The present estimates of shank and keel lengths and breast angle were comparable to the earlier reports in RIR-White strain (Das *et al*., 2014b), Libyan native chicken (El-Safty, 2012), Ardennaise chicken (Lariviere *et al*., 2009), Kadaknath and Aseel (Chatterjee *et al*., 2007) and Giriraja and WLH chickens (Adebambo *et al.,* 2006). The attributed difference was due to the different strain, line or breed studied different management and rearing system.

Feed consumption efficiency traits: Least squares means of live body Weight Gain (WG), Feed Consumed (FC) and Feed Conversion Ratio (FCR) in various age groups are presented in Table 2. The present FCR estimates were in agreement to the earlier reports for Ardennaise chicken (Lariviere *et al*., 2009) excluding 6th and 8th week FCR estimates which were poor than the report. On contrary, the FCR estimates were higher than the reports in RIR-White strain excluding 12th week FCR (Das *et al*., 2014b). The means estimates for body weight gain were better, but estimates for feed consumption and FCR were poor as evident when compared to the earlier available reports in four genetic groups of feathered, frizzled, naked neck and naked neck-frizzled chickens (Mahrous *et al.,* 2008). What so ever discrepancy might be attributed due to the strain, line or breed difference and different facets of management practices.

Table 1: Least squares Means±Standard Errors of various body conformation traits in RIR selected line chicken

	Least squares Means±Standard Errors									
Factors	CW (g)	BW4 (g)	SL4 (cm)	KL4 (cm)	BA4 (°)	BW6 (g)	SL6 (cm)	KL6 (cm)	BA6 (°)	BW8 (g)
Overall	37.31±0.59 (100)	201.92±6.51 (51)	4.42±0.06 (51)	4.61±0.07 (51)	39.08±0.52 (51)	327.84±6.31 (98)	5.73±0.04 (98)	5.83±0.04 (98)	44.09±0.41 (98)	503.44±12.21 (81)
Sex										
Male	37.68±0.64 (62)	211.42±8.11 (29)	4.49±0.09 (29)	4.67±0.09 (29)	39.71±0.62 (29)	347.27±7.57^{a} (61)	5.87±0.06^{a} (61)	5.98±0.05^{a} (61)	45.28±0.49^{a} (61)	540.26±14.71^{a} (48)
Female	36.94±0.70 (38)	192.43±8.51 (22)	4.36±0.09 (22)	4.54±0.10 (22)	38.45±0.64 (22)	308.41±8.89^{b} (37)	5.59±0.07^{b} (37)	5.67±0.07^{b} (37)	42.89±0.58^{b} (37)	466.62±16.01^{b} (33)

Factors	SL8 (cm)	KL8 (cm)	BA8 (°)	BW12 (g)	SL12 (cm)	KL12 (cm)	BA12 (°)	BW16 (g)	SL16 (cm)	KL16 (cm)	BA16 (°)
Overall	6.87±0.09 (81)	7.33±0.09 (81)	50.45±0.32 (81)	940.53±22.61 (97)	8.69±0.07 (97)	8.90±0.07 (97)	56.86±0.52 (97)	1352.99±34.59 (87)	9.91±0.09 (87)	10.41±0.10 (87)	60.90±0.57 (87)
Sex											
Male	7.13±0.10^{a} (48)	7.65±0.10^{a} (48)	51.58±0.41^{a} (48)	1031.26±26.16^{a} (60)	9.07±0.09^{a} (60)	9.22±0.09^{a} (60)	58.75±0.59^{a} (60)	1530.08±40.05^{a} (53)	10.61±0.12^{a} (53)	10.82±0.12^{a} (53)	63.37±0.66^{a} (53)
Female	6.62±0.11^{b} (33)	7.01±0.10^{b} (33)	49.32±0.45^{b} (33)	849.79±29.84^{b} (37)	8.30±0.11^{b} (37)	8.59±0.11^{b} (37)	54.98±0.67^{b} (37)	1175.91±44.59^{b} (34)	9.21±0.14^{b} (34)	10.00±0.14^{b} (34)	58.43±0.74^{b} (34)

CW: Chick weight, BW: Body weight, SL: Shank length, KL: Keel length and BA: Breast angle different periods of ages in weeks, Means within a factor having different superscripts differ significantly ($p<0.05$), Figures within parenthesis denote number of observations

Table 2: Least squares means±standard errors of feed consumption and efficiency traits in RIR selected line chicken

		Least squares means±standard errors							
Factors	Obs	WG4 (g)	FC4 (g)	FCR4	WG6(g)	FC6 (g)	FCR6	WG8 (g)	FC8 (g)
Overall	98	164.07±4.86	525.53±7.05	3.34±0.08	126.40±3.59	660.09±8.14	5.60±0.19	167.84±5.37	1203.13±5.66
Male	61	174.50±5.78[a]	527.46±7.10	3.15±0.10[a]	134.84±4.59[a]	662.17±8.20	5.41±0.25	183.86±6.65[a]	1204.57±5.70
Female	37	153.64±6.70[b]	523.60±7.16	3.54±0.13[b]	117.96±5.55[b]	658.02±8.27	5.80±0.31	151.82±7.90[b]	1201.69±5.75

		Least squares means±standard errors						
Factors	Obs	FCR8	WG12 (g)	FC12 (g)	FCR12	WG16 (g)	FC16 (g)	FCR16
Overall	98	7.71±0.21	446.26±15.76	2107.53±11.72	5.13±0.20	420.30±14.73	2398.89±7.84	5.84±0.26
Male	61	6.97±0.28[a]	502.99±18.01[a]	2110.52±11.81	4.58±0.26[a]	484.38±17.87[a]	2400.86±7.99	4.82±0.32[a]
Female	37	8.45±0.35[b]	389.54±20.35[b]	2104.54±11.91	5.68±0.32[b]	356.21±20.99[b]	2396.92±8.16	6.86±0.38[b]
Feeding group								
1	48	8.25±0.73	466.07±35.46	2128.32±12.82[b]	5.37±0.66	365.45±39.72	2421.80±9.64[b]	7.27±0.72[b]
2	50	7.18±0.73	426.46±35.45	2086.74±12.82[a]	4.89±0.66	475.15±39.72	2375.98±9.64[a]	4.41±0.72[a]

WG: Live body weight, FC: Feed consumed in gram and FCR: Feed conversion ratio at different periods of ages in weeks, respectively; Means within a factor having different superscripts differ significantly (p<0.05)

Genetic and non-genetic factors: Sires significantly (p<0.05) affected the estimates of all body conformation traits throughout the ages excepting 6th week's all estimates and estimates of 8th week's breast angle, 12th and 16th weeks' shank and keel lengths. Sire also influenced (p<0.05) the estimates of body weight gain at 12th week and feed consumption throughout the ages but sires did not affect FCR estimates at any age. Chicks' sex also affected (p<0.05) the estimates of all body conformation traits at 6th week of ages onwards; males being better than females throughout the ages (Table 1). Sex also demonstrated its influence (p<0.05) on body weight gain and FCR estimates throughout the ages excepting FCR at 6th week; males being better than females throughout the ages. Feed Consumed (FC) in grams significantly (p<0.05) varied among the feeding groups throughout the ages, thus affected also the body weight gain and or FCR to vary (p<0.05) among the feeding groups (Table 2).

Literature regarding this sire-effect could not be made available. Significant sex-differentiation in this context was previously reported in RIR-White strain (Das *et al.,* 2014b), native Libyan chicken (El-Safty, 2012), Ardennaise chicken (Lariviere *et al.*, 2009) and Giriraja, Indian WLH and Nigerian improved indigenous chicken genotypes (F_1, F_2 and B-α chickens) (Adebambo *et al.,* 2006). Das *et al.* (2014b) also obtained varied estimates of feed consumption along with body weight gain and or FCR in different feeding groups in RIR-white strain.

Genetic and phenotypic parameters

Heritability estimates: All the studied traits excluding Feed Consumption (FC) were heritable at low to high magnitude (Table 3 and 4). The heritability estimates ranged from 0.453-0.909 for BW, 0.165-0.606 for SL, 0.090-0.996 for KL, 0.282-0.853 for BA, 0.186-0.868 for WG and 0.208-0.452 for FCR. Reports in this context were limited. Adebambo *et al.* (2006) estimated corresponding 3rd and 6th week's heritability estimates of shank length as 0.916 and 0.761. Falconer (1989) stated that heritability is a property of a trait of the population nourished by some environmental circumstances. Thus, any change in the components of variance will likely change the estimate of heritability and this may explain the attributed differences in the estimates by different workers. Heritability estimates may also be influenced by other factors not considered in the model used in this study.

Genetic correlation estimates: The estimates of genetic correlations coefficients (r_G) were positive in trends and extreme high in magnitude uniformly among all the intra-week body conformation traits (Table 3). The r_G ranged from 0.678-0.944 between SL and BW, 0.626-0.945

Table 3: Heritability estimates (at diagonal), genotypic (above diagonal) and phenotypic (below diagonal) correlations among various intra-week body conformation traits in RIR selected line chicken

Traits	BW4	SL4	KL4	BA4
BW4	0.843±0.674 (49)	0.678±0.225 (51)	0.626±0.247 (51)	0.883±0.078 (51)
SL4	0.669 (51)	0.366±0.655 (49)	0.756±0.180 (51)	0.617±0.247 (51)
KL4	0.679 (51)	0.882 (51)	0.090±0.629 (49)	0.833±0.160 (51)
BA4	0.864 (51)	0.575 (51)	0.718 (51)	1.030±0.673 (49)
Traits	BW6	SL6	KL6	BA6
BW6	0.453±0.390 (98)	0.802±0.128 (51)	0.887±0.097 (51)	0.858±0.171 (98
SL6	0.627 (98)	2.161±0.550 (51)	0.874±0.089 (51)	0.612±0.208 (51)
KL6	0.697 (98)	0.730 (98)	0.188±0.640 (49)	0.531±0.874 (49)
BA6	0.875 (98)	0.504 (98)	0.637 (98)	0.404±0.384 (98)
Traits	BW8	SL8	KL8	BA8
BW8	0.567±0.465 (79)	0.683±0.211 (81)	0.909±0.142 (81)	0.911±0.092 (81)
SL8	0.573 (81)	0.606±0.469 (79)	0.832±0.097 (81)	0.704±0.268 (81)
BA8	0.901 (81)	0.544 (81)	0.519 (81)	0.282±0.431 (79)
KL8	0.607 (81)	0.825 (81)	0.996±0.495 (79)	0.898±0.245 (81)
Traits	BW12	SL12	KL12	BA12
BW12	0.722±0.422 (97)	0.944±0.268 (97)	0.917±0.251 (97)	0.898±0.094 (97)
SL12	0.745 (97)	0.274±0.369 (97)	0.849±0.262 (97)	0.603±0.414 (97)
KL12	0.749 (97)	0.857 (97)	0.290±0.371 (97)	0.533±0.416 (97)
BA12	0.871 (97)	0.626 (97)	0.691 (97)	0.807±0.429 (97)
Traits	BW16	SL16	KL16	BA16
BW16	0.909±0.464 (87)	0.940±0.155 (51)	0.945±0.106 (51)	0.976±0.046 (87)
SL16	0.636 (87)	0.165±0.384 (87)	1.469±1.006 (87)	0.842±0.148 (51)
KL16	0.750 (87)	0.750 (87)	0.401±0.418 (87)	0.913±0.078 (51)
BA16	0.904 (87)	0.625 (87)	0.795 (87)	0.853±0.461 (87)

Figures within parenthesis denote number of observations, BW: Body weight , SL: Shark length, KL: Kell length, BA: Breast angle

between KL and BW, 0.858-0.976 between BA and BW, 0.756-0.874 between SL and KL, 0.531-0.913 between KL and BA and 0.603-0.842 between BA and SL at various weeks of age. Whereas, Adebambo *et al.* (2006) reported range of r_G among body weight and other linear body measurements as -0.016-0.67 in Giriraja, Indian WLH and Nigerian improved indigenous chicken genotypes.

Similarly, in case of feed efficiency traits (Table 4), the present r_G between FC and FCR ranged from 0.191-0.539 excluding other estimates being statistically non-precise might be due to less paternal half-sibs under each sire. The r_G between WG and FC ranged from 0.603-0.673 at 4-6th weeks of age and -0.003-0.364 at 8-16th weeks. Only at 16th week, FCR showed positive genetic correlation with 6th and 12th week WG, whereas negative with 8th week WG, being other estimates statistically non-precise might be due to less paternal half-sibs under each sire; thus could not follow any definite trend. Comparable literatures could not be made available.

Phenotypic correlation estimates: The phenotypic correlations coefficients (r_P) were invariably positive in trends and high in magnitude uniformly among all the intra-week body conformation traits (Table 3). The r_P ranged from 0.573-0.745 between BW and SL, 0.607-0.750 between BW and KL, 0.871-0.904 between BW and BA, 0.730-0.882 between SL and KL, 0.519-0.795 between KL and BA and 0.504-0.626 between BA and SL at various weeks of age (Table 3).

Similarly, the r_P between WG and FC ranged from 0.0-0.186 at various weeks of age (Table 4). The r_P between FC and FCR were very low in magnitude and could not follow any definite trend. But FCR and WG were invariably negatively correlated with r_P range of -0.040 to -0.900 at various weeks. The present findings were in accordance to the earlier reports in RIR-White strain (Das *et al.*, 2014b). Adebambo *et al.* (2006) found the r_P among body measurement parameters as lower at older ages (-0.018-0.711) than at younger ages (-0.081-0.828). Phenotypic associations of body weights with keel angle and keel length were also reported in Ardennaise chicken (Lariviere *et al.*, 2009). It was suggested that the phenotypic correlations were influenced by the magnitude and signs of the genetic and environmental correlations, it was of interest to compare

Table 4: Heritability estimates (at diagonal), genotypic (above diagonal) and phenotypic (below diagonal) correlations among feed consumption and efficiency traits in RIR selected line chicken

Traits	WG4	FC4	FCR4	WG6	FC6
WG4	0.565±0.422	0.604±0.314	-0.813±2.035	-0.318±0.986	0.603±0.310
FC4	0.186	>1.0	0.007±0.514	0.695±0.761	>1.0
FCR4	-0.920	0.053	0.208±0.387	>1.0	0.029±0.514
WG6	0.009	0.155	-0.045	0.186±0.385	0.673±0.746
FC6	0.205	0.993	0.029	0.155	>1.0
FCR6	0.118	-0.020	-0.055	-0.859	-0.014
WG8	0.191	0.060	-0.233	0.145	0.062
FC8	0.205	0.993	0.029	0.155	1.000
FCR8	-0.211	0.026	0.272	-0.216	0.028
WG12	0.209	0.010	-0.190	0.399	0.009
FC12	0.207	0.992	0.027	0.152	1.000
FCR12	-0.133	0.086	0.162	-0.315	0.092
WG16	0.015	0.112	-0.041	0.229	0.126
FC16	0.145	0.918	0.068	0.151	0.924
FCR16	-0.030	-0.026	0.066	-0.109	-0.033

Traits	FCR6	WG8	FC8	FCR8	WG12
WG4	>-1.0	0.222±0.701	0.603±0.310	> -1.0	0.703±0.431
FC4	-	0.149±0.422	>1.0	-	-0.018±0.294
FCR4	-	-0.200±1.250	0.029±0.514	-	>-1.0
WG6	-	>-1.0	0.673±0.746	-	0.986±0.838
FC6	-	0.180±0.423	>1.0	-	0.004±0.294
FCR6	-	-	-	-	-
WG8	-0.099	0.330±.401	0.180±0.423	-	-0.736±0.649
FCR8	-0.014	0.062	>1.0	-	0.004±0.294
FC8	0.216	-0.890	0.028	-	-
FCR8	-0.324	0.101	0.008	-0.194	0.868±0.440
WG12	-0.013	0.063	1.000	0.029	0.004
FC12	0.322	-0.201	0.092	0.307	-0.897
FCR12	-0.199	0.235	0.126	-0.207	0.060
WG16	-0.006	0.090	0.923	-0.003	0.000
FC16	0.105	-0.157	-0.034	0.165	-0.040

Traits	WG12	FCR12	WG16	FC16	FCR16
WG4	0.703±0.431	>-1.0	0.471±0.668	0.620±0.330	-0.893±0.796
FC4	-0.018±0.294	0.539±1.944	0.091±0.374	>1.0	0.182±0.397
FCR4	>-1.0	>1.0	-0.920±1.329	-0.028±0.530	>1.0
WG6	0.986±0.838	>-1.0	0.455±0.971	0.639±0.734	0.233±1.168
FC6	0.004±0.294	0.432±1.641	0 .057±0.375	>1.0	0.204±0.399
FCR6	-	-	-	-	-
WG8	-0.736±0.649	>1.0	>1.0	0.364±0.444	>-1.0
FC8	0.004±0.294	0.433±1.642	0.057±0.375	>1.0	0.204±0.399
FCR8	-	-	-	-	-
WG12	0.868±0.440	>-1.0	-0.453±0.551	-0.055±0.303	0.624±0.634
FC12	0.004	0.452±1.692	0.066±0.375	0.998±0.010	0.191±0.399
FCR12	-0.897	0.055±0.368	0.217±2.051	0.580±2.077	-0.344±2.153
WG16	0.060	-0.044	0.435±0.411	0.036±0.388	>-1.0
FC16	0.000	0.079	0.150	>1.0	0.292±0.425
FCR16	-0.040	0.068	-0.900	-0.082	0.398±0.408

Number of observations was 98 in all estimations, WG: Weight gain, FC: Feed consumed, FCR: Feed conversion ratio

these values with each other and to make comparisons of each within and between subpopulations of breast angle and body weight when studied in White Plymouth Rock chickens at 8 weeks of age (Siegel, 1962).

CONCLUSION

It is concluded that body weights and weight gain, shank and keel lengths, breast angle and feed conversion ratio were not sex independent traits but mostly sire-influenced and heritable at variable magnitude. Their genetic and phenotypic correlation estimates were encouraging and could therefore be used to predict either conformation or percentage meat yield of the carcass. This information may serve as base information to the breeders as well as academicians and may be useful for improvement of the chicken line.

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